United States Department of Agriculture
Region 8, Soil Conservation Service
Albuquerque, N. Mex.

EARTH DAMS: A TENTATIVE OUTLINE OF REGIONAL POLICY COVERING IMPORTANT ELEMENTS IN INVESTIGATION, DESIGN, AND CONSTRUCTION

Regional Bulletin No. 14
Engineering Series No. 2
July 1937

Theory alone is no substitute for thorough field investigation, careful selection of material, and proper methods of construction, but the application of scientific methods of procedure and theoretical interpretation of field data is the modern trend in earth dam design and construction. The solution of the problem calls for the collective efforts of both engineers and soils men and to this end the following summary for a systematic procedure is presented; assuming that the justification for the project has already been provided, hydrologic and hydrographic studies have been made, and data on the topography of the drainage basin and tentative sites are available.

1. Reconnaissance at the various sites establishes suitability from the standpoint of topography. The presence of a spring or natural seepage as the surface indication of a ground water flow characteristic should be recognized as a potential danger and treated as such.

2. Subsurface and foundation investigation by means of judiciously located test pits or drill holes (or a combination of both) at the dam site, reservoir and borrow pits should provide:- a log of the soils, ground water, impervious stratum and/or geologic formation. Requirements of depth for the test pits are subject to some qualification as indicated by the size and importance of the structure. However, as an essential element in the subsequent determination of the line of saturation, the depth of soil cover over the impervious stratum and the position of ground water level should be ascertained. A dangerous condition of saturation is often due to the shallow depth of impervious stratum. Foundation material tests should cover:- bearing strength under conditions of saturation, porosity, dry weight per cubic foot, linear shrinkage and degree of dispersion of the clay fraction.

3. The characteristics of the individual soils available from borrow pits and the mixture which will be necessary to meet the specifications will be determined by means of:-

(a) Mechanical analysis

(b) Rate of percolation through application of Proctor's method and Slichter's formula.

(c) Line of saturation as affected by:- speed of flow, determined by Proctor's method; distribution of particles comprising the materials in the dam; distribution, depth and character of soil under the dam; the flow of ground water and its depth below the original surface; the use of core or upstream impervious blanket; and drainage of the downstream portion of the dam.

(d) Degree of dispersion and determination of limiting velocity of flow through fill to preclude "piping".

In the selection of fill materials, soils that are composed largely of gypsum or carry appreciable amounts of substances soluble in water (alkali salts) should, in general, be regarded as unsuitable. The danger in the use of soils containing large percentages of colloidal or fine clays is recognized and special treatment should be required in cases where there is sufficient justification for their use.

4. Borrow pits should be thoroughly prospected and the quantities predetermined. The factor of prime importance in their selection is soil suitability; however, consideration should be given, whenever practicable, to their location as affecting land use and economical construction.

5. Design of the cross section cannot be properly undertaken prior to the determination of requirements dictated from the foregoing tests and studies. Minimum requirements for the upstream slope should be the underwater angle of repose of the material in the fill and for the downstream slope somewhat flatter than the angle of repose of the dry material. It is sometimes necessary to use flatter slopes both upstream and downstream in order to obtain increased bearing area. Unless the quality and bearing strength of the foundation soil is unquestionable, it should be thoroughly investigated.

THE PROFILE OF THE LINE OF SATURATION or the uppermost line of flow of the water through the dam and subsoil and the LOCATION OF THE POINT WHERE IT CUTS THE BASE are the limiting factors in determining the minimum cross-section. The accuracy with which the position of this line may be predicted, for a given site, depends largely upon the thoroughness with which the preliminary field data and subsurface investigations are carried out.

It is desirable, whenever possible, to design the compacted fill as a single and substantially uniform section, although modification in this respect may be necessary, depending upon the quantities and characteristics of the soils available. When the use of a core section is indicated as necessary, its position relative to the axis of the dam is also of some importance. The width of the core section is somewhat dictated by the requirements of clearance for the operation of the compacting equipment, but the determining factor in important structures is the width necessary for proper resistance to percolation at all levels,- the passage of any water being assumed as under the core. Particular attention should be given to keying the core into the abutments and foundation, and the sides of the trench should be sloped sufficiently to meet the requirements of safety and economy.

The problem of design of details such as freeboard, crest width,

and face protection usually permit of a strictly engineering solution.

The limiting factors in the determination of minimum freeboard are:- extreme height of greatest flood expected, maximum height of waves and depth of front line, but the selection of soil for this portion of the dam is also important and, in order to avoid the necessity of overbuilding to allow for cracking, their selection should be limited to those of low linear shrinkage and, as further protection, that portion of the structure should be blanketed with aggregated materials to reduce the speed of evaporation and subsequent cracking.

Particular attention should also be given to crowning the crest of the dam sufficiently to provide adequate drainage and reduce the danger of erosive concentrations of rainfall.

Where vegetative cover is not practicable, the effectiveness of a complete blanket of coarse sand or gravel goes farther than mere face protection, and as a measure to provide drainage, to increase stability, and minimize the tendency of sloughing, the placing of a coarse rock fill at the downstream toe embodies principles of good practice.

6. In addition to the usual requirements for preparation of the site, such as clearing, grubbing, provisions for drainage on the downstream side, and bonding the foundation to the fill, consideration should be given to the proper sloping of the abutments (the sides of the gully or arroyo).

It is, of course, agreed that there shall be no sharp breaks in the side slopes or where the sides join the bottom. A limiting value for side slopes may be considered as not less than the angle of repose of the saturated material. This, of course, will usually be steeper than the face slopes of the fill as the abutments are composed of soil in its natural bed. Economic consideration may indicate an even flatter slope for the efficient operation of construction equipment.

7. Construction represents the proper assembling in the field of the various elements of design which were determined from results of the investigational work. The recomposition should be so controlled that the finished structure retains its predetermined characteristics.

Proper compaction is the basic requirement in the construction operation, irrespective of the methods used in obtaining it. The effectiveness of the methods used involves a consideration of soils and soil mixtures and the effect upon them by the following variable elements; namely, moisture, weight of compacting equipment, number of trips over each layer of fill material, and the thickness

of the layers.

The Proctor method is fully applicable to compaction of all soils having low linear shrinkage at maximum compaction. The degree of dispersion will be a major factor in determining the limits of linear shrinkage permitted.

The extent to which these elements may be varied or modified are properly evaluated by means of field determinations. This procedure presupposes adequate field inspection.

The three phases in a systematic treatment of an earth dam project, INVESTIGATION, DESIGN, and CONSTRUCTION, are interdependent and of equal importance. The design is built up from the investigational work and the construction pattern is taken from the design. Projects which may involve considerable variation from the standards as outlined should be treated as special cases. The development of detailed procedure from this outline will bring under discussion such important items as: routine of soils investigation and control; maintenance and rodent control; freeboard; top width; face protection, etc.

Although the spillway is an inseparable element of any dam project and its study is undertaken with regard to its relation to the project as a whole, the importance of the problem is such as to call for individual and special consideration.

Since the phase of operations covered by this outline is at a comparatively advanced stage in the plan of action, justification for the project and the type of treatment is presupposed. Therefore work areas carry definite limitations on expenditures and the completeness with which the program may be carried out depends upon the careful administration and proficient utilization of funds. Economical designs and low construction costs provide a most positive means to increase the scope of operations.

In general, simplicity and system should be aimed at as both are essential characteristics of good engineering economics, but in striving for simplicity we should not allow ourselves the privilege of "cutting corners".